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Spin-lattice relaxation time of Sc metal

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Abstract

The spin-lattice relaxation time T_1 of Sc metal was measured at low temperatures to investigate the nuclear spin ordering of Sc metal. The Korringa constant gives information about the nuclear spin–spin interaction in metals. The reported values of the Korringa constant for Sc by several authors are distributed between 0.09 and 1.6 s K. We measured the temperature dependence, field dependence and anisotropy of T_1 of Sc metal.

Keywords: Korringa constant; NMR; Nuclear magnetism

Scandium is an exchange-enhanced Pauli paramagnet which shows a maximum of the susceptibility. The natural abundance of ^{45}Sc ($I = \frac{7}{2}$) is 100%. Since the crystal structure is HCP, the electronic quadrupole interaction between nuclear spins exists. An NQR experiment at very low temperatures by Pollack et al. [1] showed that the ground state is $\pm\frac{7}{2}$ in Sc metal with the first excited state $\pm\frac{5}{2}$ located at 18 μK (390 kHz) above the ground state. Pollack et al. also reported the Korringa constant of 90 ms K which is rather short compared with other reported values at high temperatures in rather high magnetic field, 1.6 s K [2,3], 1.1 s K [4]. Usually, the short spin-lattice relaxation time at low temperatures in low magnetic field is attributed to magnetic impurities. Small amounts of Fe impurities (19 at ppm) were found to drastically change the properties of scandium metal [5]. The Sc crystal used by Pollack et al. was grown in the same batch at Ames Laboratory as ours. Both specimens, Pollack's and ours, contain 3 ppm Fe. Our specimens contain much smaller Fe impurities than the specimens used in the previous experiments [2–4]. One intrinsic mechanism which gives the short relaxation time is the spin fluctuation of a correlated electron system [6–8]. However, later work by Pollack [9,10] determined that for their case a novel cross-relaxation mechanism specifically related to energy relationships only true at zero field was responsible for their fast relaxation times. We measured the temperature dependence, field dependence and anisotropy of the Korringa constant of Sc metal. We will compare our results with the previous data.

A single crystal used in our experiments was grown in Ames Laboratory. It has a dimension of $3.5 \times 2.0 \times 27$ mm^3 with the long direction paralleled to the *a*-axis. The relaxation time was measured by using the spin-echo technique. The measured RF frequencies were approximately 5, 7 and 11 MHz. The external magnetic field was applied parallel to the *a*- and *c*-axis. The temperature range was between 1.5 and 4.2 K. The sample holder with the crystal was immersed in the liquid helium.

Nuclear spin energy levels of Sc metal were split due to the nuclear electric quadrupole interaction, so we have to be careful in measuring the spin-echo and analyzing the data. The nuclear spin-lattice relaxation time was measured by recording the recovery of spin-echo intensity at varying delays after saturating comb pulses. In Fig. 1 the values of T_1T measured for the crystal's *c*- and *a*-axis are plotted against temperature. The resonance frequency in this measurement was 11 MHz. Results show the

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